WiseNET: smart camera network combined with ontological reasoning for smart building management

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Visual sensor networks (VSN) have become a part of our daily life [1] [2]. Based on our experience we have identified two main problems on VSN. Firstly, the problem of selecting relevant information from the huge amount of data given by the network. Secondly, the problem of integrating the information coming from the different nodes of the network, i.e., linking the different informations together in order to take a decision. These problems can be overcome by including smart cameras in charge of extracting the significant information from the scene and by adding contextual semantic information, i.e., semantic information of what the camera observes, building information and events that may occurred. Semantic information coming from different nodes can be easily integrated in an ontology. Our approach differs from standard computer vision, which deals with algorithm improvement [3] [4] and signal processing problems [5], by dealing with a *meaning problem in computer vision*, where we try to improve and understand what the camera "sees" by adding contextual semantic information.

We developed an innovative distributed system that combines smart cameras with semantic web technology. The proposed system is context sensitive and provides knowledge and logic rules in order to optimize the usage of a smart camera network. The main application of our system is smart building management, where we specifically focus on improving the services of the building users.

The WiseNET (Wise Network) system consists of a smart camera network connected to an ontological model. The communication between the smart camera network and the ontological model is bidirectional, i.e., the cameras can send information either when the model asks for it or whenever new data becomes available. The ontological model is a semantical one that allow us to express information in our system and to take decisions according to combinations of the different information [6]. The semantical model is articulated in three sections: sensor, environment and application. All the sections are bilaterally connected between themselves by properties and relations. The sensor section consists of a semantic web vocabulary concerning the smart camera, the image processing algorithms and their results [7]. The sensor section is in charge of giving a semantic meaning to what the smart cameras observes, a problem known as semantic gap [8]. The environment section is composed by a semantic web vocabulary regarding the building information model (BIM) [9]. Finally, the application section comprises a set of rules defining some events that may be important for security applications and the different decisions to take according to the occurrence of these events [10].

Some of the behaviors of the WiseNET system are:

Smart camera observes some features of interest: different image processing algorithms were applied in order to determine some features of interest such as motion, face detection, person detection [4], etc.

Smart camera sends message to the ontological model: the camera just sends messages (no images) stating the presence of a specific feature, the time and the position of the feature in the field of view (FOV). The message has to be shaped according to vocabulary defined in the semantic model.

Ontological reasoning: the ontological model combines all the messages received from the cameras and based on semantic rules it can quickly infer new knowledge and/or take some decisions. The decisions can be categorized in three types. Firstly, rules dedicated to event identification, such as profiling the behavior of a person, incorrect use of the building elements, presence of somebody on a restricted area, an abandoned object [10], etc. Secondly, rules to alert users about the occurrence of certain event, such as alerting the closest person to help somebody that fell, calling security if somebody is in a restricted area or if an object has been abandoned, alerting that somebody is stuck in the elevator, etc. Finally, rules dedicated to improve the visualization of features, i.e., change the image processing algorithm according to the features that want to be detected or just to take into consideration the environmental changes such as light, events, if a door is closed, the position of a furniture, etc.

Smart camera receives a message from the ontological model: there are two types of messages. Firstly, the camera can be asked to change the image processing algorithm in order to adapt to its context or to detect a specific feature of interest. Secondly, the camera can be asked to search, in a specific part of the FOV, for a certain feature of interest. This can be used to confirm or double check an inferred knowledge.

The standard computer vision can be greatly enhanced by adding semantic information of the context. The WiseNET system improves the standard computer vision approaches by handling in a optimal way the data coming from the network, by adding a correction procedure and by giving a method to change the image processing algorithm in order to better adapt to the context. Also the WiseNET system overcomes the standard privacy/utility trade off present on classical VSN systems [1] [2]. In conclusion our system can increase services for the users of the building either in their daily activities, as their welfare and safety.

Keywords—Visual sensor network, Image processing, Knowledge engineering, Semantic gap, Building Information Modeling (BIM), Event detection

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